Statistical Properties of Systems with Damage and Defects

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Christopher A. Serino

Boston University, Graduate School of Arts and Sciences, 2012

Major Professor: William Klein, Professor of Physics

ABSTRACT

In this dissertation we will examine the effect microscopic defects have on macroscopic properties of classical, many-body systems using simple models with many coupled degrees of freedom, where some of those degrees of freedom are quenched into a defective or damaged state. These simple models are constructed as cellular automata whose temporal evolution is controlled by a rule that depends only on the value of the cell evolving and the values of that cell's nearest $q \sim R^d$ neighbors, where R is the interaction range. Damaged or defective elements are then defined as cells that do not follow this evolution rule as the system is advanced in time. We concentrate on two classes of materials: building and support materials, and solid earth. In the case of the former, it is known these materials experience fatigue and thus become increasingly susceptible to catastrophic failure (e.g. the snapping of a support cable) over time. By first determining the steady-state properties of our models in the absence of damage, we measure whether or not the system remains in a metastable-equilibrium-like state as the catastrophic event is approached. We also consider the geometry of the catastrophic event and find it is controlled by the interaction range. Finally, in our examination of the onset of the catastrophic event, we find the dissipation parameter controls not only the failure rate, but also the number and amplitude of precursory events. In the case of solid earth, we focus on Gutenberg-Richter scaling: an empirical observation that the frequency of seismic events with a seismic scalar moment of at least μ on a fault system are power-law distributed as $f \sim \mu^{-2b/3}$. Our model fault

system consists of individual faults with quenched damage whose frequency-moment statics scale as an exponentially suppressed power-law in μ. Scaling on the model fault system is then controlled by this distribution, as well as the relative frequency with which a fault with a given amount of damage occurs within the fault system. By varying this frequency, we can generate statistics with Gutenberg-Richter b-values consistent with seismological observations in the range $0.8 \lesssim b \lesssim 1.3$.